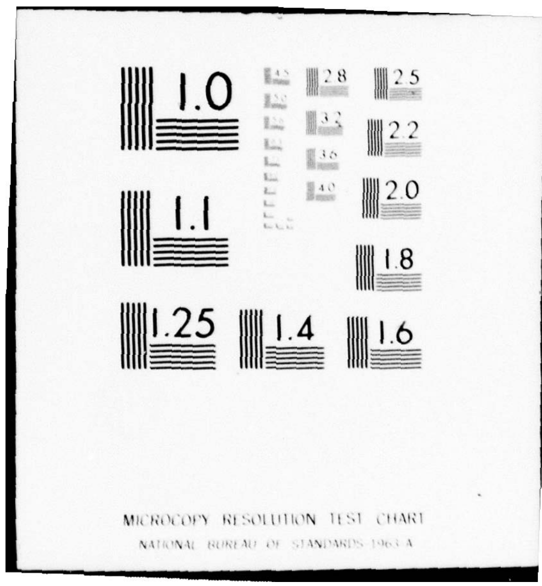
AD-A054 605 NATIONAL AVIATION FACILITIES EXPERIMENTAL CENTER ATL--ETC F/G 17/7
TRSB MICROWAVE LANDING SYSTEM DEMONSTRATION PROGRAM AT CAPE MAY--ETC(U)
OCT 77

UNCLASSIFIED FAA-NA-78-13 FAA-RD-78-13 NL

1 OF 1
AD
A054605

END
DATE
FILMED
7-78
DDC


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

Report No. FAA-RD-78-13

FOR FURTHER TRAN

12

TRSB MICROWAVE LANDING SYSTEM DEMONSTRATION PROGRAM AT CAPE MAY, NEW JERSEY, U.S.A.

SEPTEMBER - OCTOBER 1977

FINAL REPORT

Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161.

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research & Development Service
Washington, D.C. 20590

NOTICE

METRIC CONVERSION FACTORS

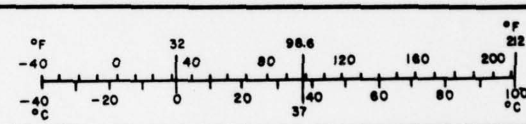
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



18 19

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. FAA-RD-78-13	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle 6 TRSB Microwave Landing System Demonstration Program at Cape May, New Jersey, U.S.A.		5. Report Date September - October 1977 6. Performing Organization Code
7. Author(s)		8. Performing Organization Report No. 14 FAA-NA-78-13
9. Performing Organization Name and Address Federal Aviation Administration National Aviation Facilities Experimental Center Atlantic City, New Jersey 08405		10. Work Unit No. 11. Contract or Grant No. 075-725-700
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Systems Research and Development Service Washington, D.C. 20590	9	13. Type of Report and Period Covered Final Report. 27 Sep[redacted]-Oct[redacted]77 14. Sponsoring Agency Code 8
15. Supplementary Notes 11 8 Oct 77 12 32p.		

16. Abstract

The Small Community (SC) TRSB MLS built by the Bendix Corporation was demonstrated at the Cape May County Airport, September 27 to October 8, 1977.

The SC system provides proportional guidance over an azimuth sector of +10 degrees about the runway centerline with clearance signals out to +40 degrees. Proportional guidance is provided in elevation from 2 degrees to 11 degrees. Fly-down clearance is provided from 11 degrees to 15 degrees. System coverage is at least 20 nautical miles in heavy rain.

Demonstration flights were conducted using a DC-6 and a "Twin Otter." Data were collected utilizing a radio theodolite. Results of these tests indicate;

1. The system required minimal site preparation and installation time,
2. The system was subjectively determined to have very good guidance characteristics,
3. The "Small Community System" exceeds its design specifications,
4. For this airport and runway, guidance signal quality is well within ICAO requirements for a "reduced capability system," and
5. The "Small Community" TRSB configuration path and course signal structure meets Category II ILS requirements.

17. Key Words Cape May TRSB MLS Small Community System	18. Distribution Statement Document is available to U.S. public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	29	

Form DOT F 1700.7 (8-69)

240 550 LB

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

INTRODUCTION

During the past several years, extensive engineering evaluation and flight testing has been accomplished on Time Reference Scanning Beam (TRSB) Microwave Landing System (MLS) equipments at the Federal Aviation Administration's (FAA) National Aviation Facilities Experimental Center (NAFEC), Atlantic City, New Jersey, and at the Auxiliary Naval Landing Field, Crows Landing, California. TRSB MLS is the United States and the Australian candidate submission to ICAO as the future all-weather landing system which would replace ILS.

In March 1977, the ICAO All Weather Operations Panel (AWOP) recommended TRSB to the Air Navigation Commission (ANC) as the preferred candidate system for international adoption. This decision by AWOP followed a 15-month period of intensive and comprehensive assessment of all competing microwave landing systems conducted by a working group of international experts under the sponsorship of the AWOP. The ANC forwarded the AWOP recommendations to the ICAO Council, whereupon the Council has scheduled a worldwide meeting for April 1978, to address the question of selecting the new international standard for an approach and landing system to replace ILS. Meanwhile, the Council has encouraged proposing States to conduct demonstrations and flight trials at operational airports. Accordingly, the FAA has developed a program to conduct operational demonstrations of several TRSB hardware configurations at selected airports in the United States and abroad. These demonstrations are intended to show that TRSB is a mature system that meets the full range of requirements from general aviation use to scheduled air carrier operations, for Category I to Category III autoland, under good or poor airport siting conditions, and under extreme weather conditions. Additionally, these demonstrations provide opportunities for representatives and officials of the international aviation community to gain first hand knowledge of TRSB MLS, and assess its applicability to their particular requirements.

The initial site selected for an operational evaluation, partly due to its proximity to NAFEC, is a small municipal airport located approximately 45 miles (72 kilometers) southwest of NAFEC in Cape May, New Jersey. The airport, although primarily intended for general aviation use, is served by a domestic feeder airline with four daily flights using Dehaviland DHC-6 Twin Otter aircraft. The airport has four runways, two are 4000 feet (1.22 kilometers) in length and two are 5000 feet (1.52 kilometers) in

length. The airport plan view is presented in Figure 1. At the present time, the airport is equipped for VOR non-precision approaches only, with 600-foot/1 mile (183 meters/1.6 kilometers) minimums.

DISCUSSION

The TRSB system configuration selected for installation at the Cape May County Airport was manufactured by the Bendix Corporation's Communications Division, in accordance with FAA specifications (see Table 1). It is the most economical system configuration developed in the U.S. Phase III program, and was designed to provide azimuth proportional guidance over an area of plus and minus 10 degrees about runway centerline, with directional guidance (i.e., fly left or right) from 10 degrees out to 40 degrees similar to an ILS localizer. The elevation proportional guidance extends from 2 degrees to 11 degrees. Fly-down clearance is provided from the upper limit of proportional guidance to 15 degrees. System coverage distance is at least 20 nautical miles under heavy rain conditions, and much greater under less stringent environmental conditions. Basically, the small community TRSB was designed to provide Category I operational minimums on most runways in most airport environments. Guidance quality, however, has been shown to be better than ILS, and will support autoland operations. General information on TRSB is presented in the Appendix.

System Installation

A survey team from NAFEC visited the Cape May Airport on September 13, 1977, and selected an installation site for the system to serve Runway 10, a 5000-foot runway (1.52 kilometers) with the azimuth subsystem site located along the extended centerline 600 feet (183 meters) beyond the stop end of the runway. The elevation subsystem site was located 210 feet (64 meters) perpendicular to the centerline, on the north side of the runway, and 860 feet (262 meters) from threshold. The sites are best visualized by referring to Figure 2. It is evident from this diagram and Figure 3, that the azimuth site selected could possibly be susceptible to multipath interference from several structures near the south side of the runway, most notably a four story terminal building and a hangar; however, subsequent tests revealed no observable multipath effects. Experience indicates that an ILS localizer in this location would produce observable multipath in the approach and landing zone.

Two weeks following the site survey, the "Small Community System" was transported to the airport over a very rough road by truck, unpacked,

installed, turned on, ground checked, and certified ready for use. About 1-1/2 days of elapsed time was required between equipment arrival at the airport and the completion of all ground performance checks. Because of the short time duration of testing and demonstration activities (September 27 to October 8, 1977), power was provided by a small diesel generator at each site.

Figure 3 shows the azimuth subsystem in the foreground, with the far field monitor horn located forward of the antenna on runway centerline. The view is toward the runway. All of the azimuth subsystem electronics and antenna are located in the one housing shown. Figure 4 presents another view of the azimuth subsystem from the runway end. The monitor horn appears in the foreground, and the azimuth antenna is located directly behind the white radome visible in the background. A closeup view of the azimuth field monitor antenna is presented in Figure 5.

The elevation subsystem and its far field monitor are shown in Figure 6. As in the case for azimuth, the elevation subsystem, including antenna and electronics, is totally housed in the one structure shown. The elevation monitor horn is located 150 feet (45.7 meters) in front of the array on a pole, 11.75 feet (3.58 meters) high. The runway is visible along the left side of the figure.

As observed in Figures 3 through 6, it is significant to note the relative ease of installation, requiring only four concrete foundations to support the two subsystems and their respective monitors.

Operational Demonstrations

On October 7, 1977, an FAA/NAFEC Douglas DC-6 aircraft flew conventional 3-degree approaches to the TRSB instrumented, runway (R/W 10/28). A typical DC-6 3-degree approach on TRSB guidance is shown in Figure 7. The TRSB elevation guidance subsystem appears in the right center of the picture. During the afternoon of October 7, a series of approaches were tracked to obtain data on the quality of TRSB guidance at this particular airport.

The Canadian Department of Transportation participated in the operational evaluation by sending their flight inspection "Twin Otter" aircraft (see Figure 8) and crew to NAFEC to be equipped with TRSB receivers. Following the equipment installation, the "Twin Otter" conducted flights on

September 28, 29, 30, 1977, at the Cape May Airport. These flights consisted of 3-degree and 6-degree approaches and landings using on-board area-navigation to the interception of the TRSB guidance. Representatives of the press and aviation officials participated in these demonstrations. No ground tracking was accomplished.

Figure 9 shows the Canadian "Twin Otter" on the final segment of a 6-degree approach using the TRSB elevation and azimuth guidance. The "Twin Otter" is shown again in Figure 10 approaching the azimuth subsystem after taking off from Runway 10/28. According to the "Twin Otter" pilot, Joseph Czaja, "The Small Community System provided very good precision MLS guidance to Runway 10." He also stated that, "All members of the crew were very well satisfied with its performance."

Performance Assessment

A Radio Telemetry Theodolite (RTT) tracked the position of the DC-6 on a series of data flights conducted on the afternoon of October 7, 1977. Four elevation runs and four azimuth runs were tracked independently. The RTT was adjusted on the ground to have the same sensitivity as the TRSB system. While manually tracking the aircraft with the theodolite, the RTT angle data was simultaneously transmitted to the aircraft, where it was received, decoded, and combined with the TRSB signal to produce a difference-voltage representing the angular difference between tracked angle and the TRSB guidance angle. This difference, representing system error, was plotted on an airborne strip chart recorder, together with the airborne TRSB track and the RTT track. Although the strip chart recordings for elevation and azimuth error appeared on independent runs, representative samples of each have been combined as illustrations of system performance, and are presented in Figures 11 and 12. Transferring these recordings to the figures, the azimuth zero axis has been shifted to average out azimuth alignment biases. No similar adjustment was made to the elevation data. ICAO (AWOP) noise error limit boundaries have been added to the plots as shown.

A review of Figures 11 and 12 indicates that the maximum peak-to-peak elevation noise excursion is ± 0.08 degrees, with typical excursions somewhat smaller. For azimuth guidance, with the exception of 1/2 second, the peak-to-peak noise excursions are within ± 0.07 degrees.

TRSB Small Community System performance has been shown to exceed the requirements of the FAA Phase III specifications (Table 1) as well as the more stringent specifications of ICAO (Table 2).

ICAO Annex 10 ILS Category II glide slope and localizer requirements at threshold are 17 microamperes and 5 microamperes respectively. Converting these requirements to angular data presented in Figures 11 and 12 for the Cape May runway length, the TRSB angles are ± 0.08 degrees in elevation (1 microampere = 0.0047 degrees), and ± 0.11 degrees in azimuth (1 microampere = 0.022 degrees). Therefore, the TRSB Small Community System meets path and course guidance signal quality for Category II ILS requirements.

Additional data will be published as a working paper to ICAO.

SUMMARY OF RESULTS

The TRSB system discussed in this document represents the most economical configuration of TRSB hardware thus far designed under the United States MLS development program, and within the FAA is referred to as the "Small Community System." In addition to its economical system architecture, the information presented herein indicates:

1. The TRSB system required minimal site preparation and installation time.

2. The TRSB system was judged to have very good guidance characteristics as subjectively determined.

3. The TRSB "Small Community System" exceeds its design specifications.

4. For this airport and runway, the data indicates that guidance signal quality is within ICAO requirements for a "reduced capability system."

5. The data indicates that this TRSB system configuration path and course guidance signal structure quality meets Category II ILS requirements.

TABLE 1.
TRSB ACCURACY, PHASE III SYSTEMS

			BIAS (DEG.)	PATH FOLLOWING NOISE (DEG.)	PATH FOLLOWING ERROR (DEG.)	CONTROL MOTION NOISE (DEG.)	REMARKS
Basic Narrow	AZ	SPEC	.19	.08	.2	.07	at 50' on 2.5° G/S
	EL	SPEC	.08	.09	.12	.05	
Small Community	AZ	SPEC	.29	.15	.33	.10	at 150' on 2.5° G/S
	EL	SPEC	.11	.12	.16	.10	

NOTES ON TRSB ALLOWABLE PFE DEGRADATIONS (PHASE III CONTRACTS)

	PFE Degradation W/Distance	W/Azimuth Angle	W/Elevation Angle
Basic Narrow			
Azimuth	None	Linearly to twice C/L error at ±60°	None to 9°. Linearly to 2 times from 9° to 20°
Elevation	Linearly to 1.5 times at 20 NM	None	Linearly to 3 times from 2.5° to 20°
Small Community			
Azimuth	Linearly to 0.4° at 20 NM	Linearly to twice C/L error at ±60°	None to 9°. Linearly to 2 times from 9° to 15°
Elevation	Linearly to 1.5 times at 20 NM	None	Linearly to 3 times from 2.5° to 15°

TABLE 2.

ICAO (AWOP) REDUCED CAPABILITY CONFIGURATION ERROR LIMITS

AWOP System Configuration	Distance to Error Window	Permitted Error (2 Sigma) Feet	Degrees
Reduced Capability (Elevation)	4000	10	0.14 ±.1 noise ±.1 bias
Reduced Capability (Azimuth)	10,000	±40	±0.23 ±.16 noise ±.16 bias

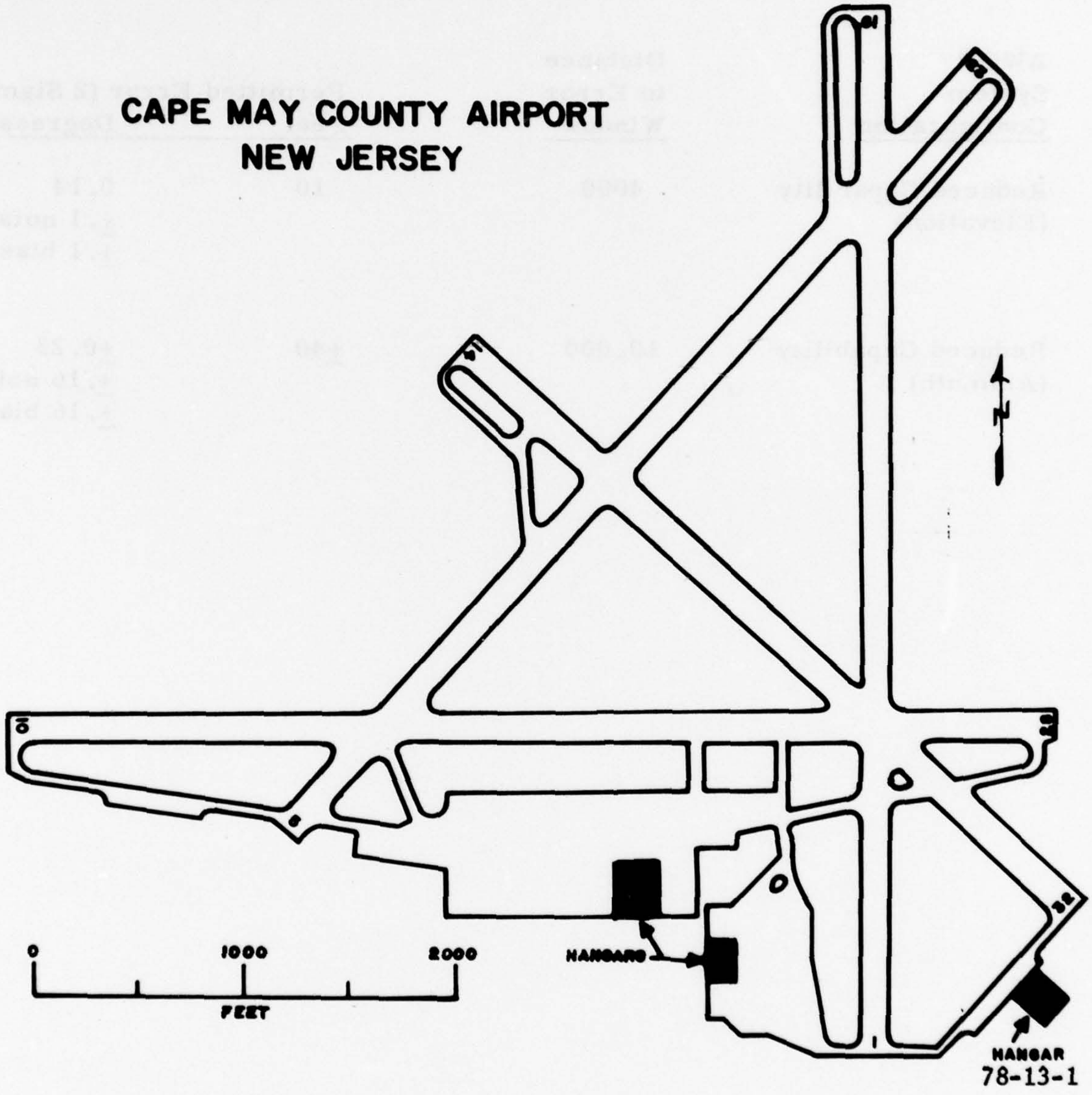


FIGURE 1. CAPE MAY COUNTY AIRPORT, NEW JERSEY

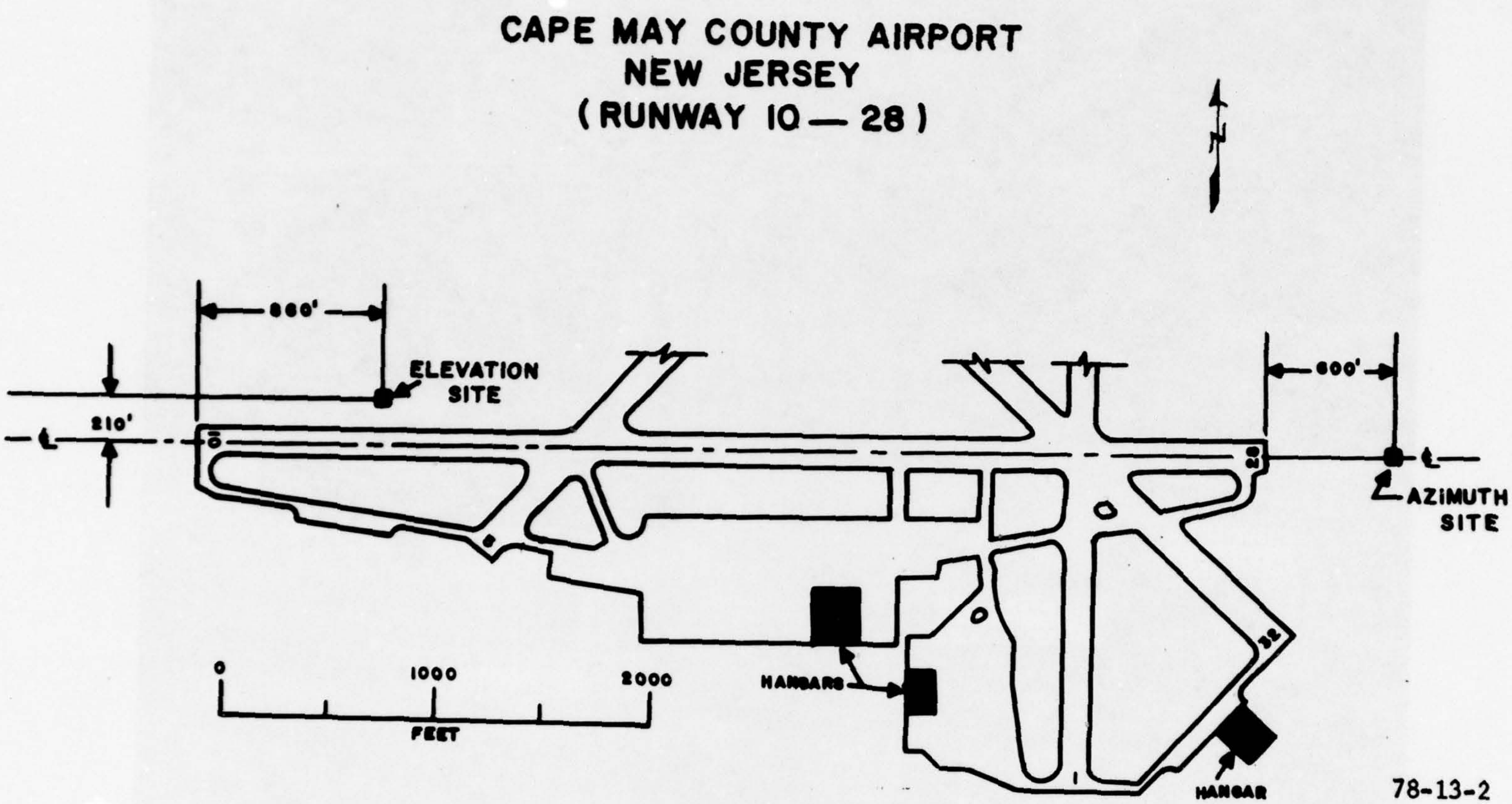


FIGURE 2. LOCATION OF TRSB SMALL COMMUNITY AZIMUTH AND ELEVATION SUBSYSTEMS ON RUNWAY 10

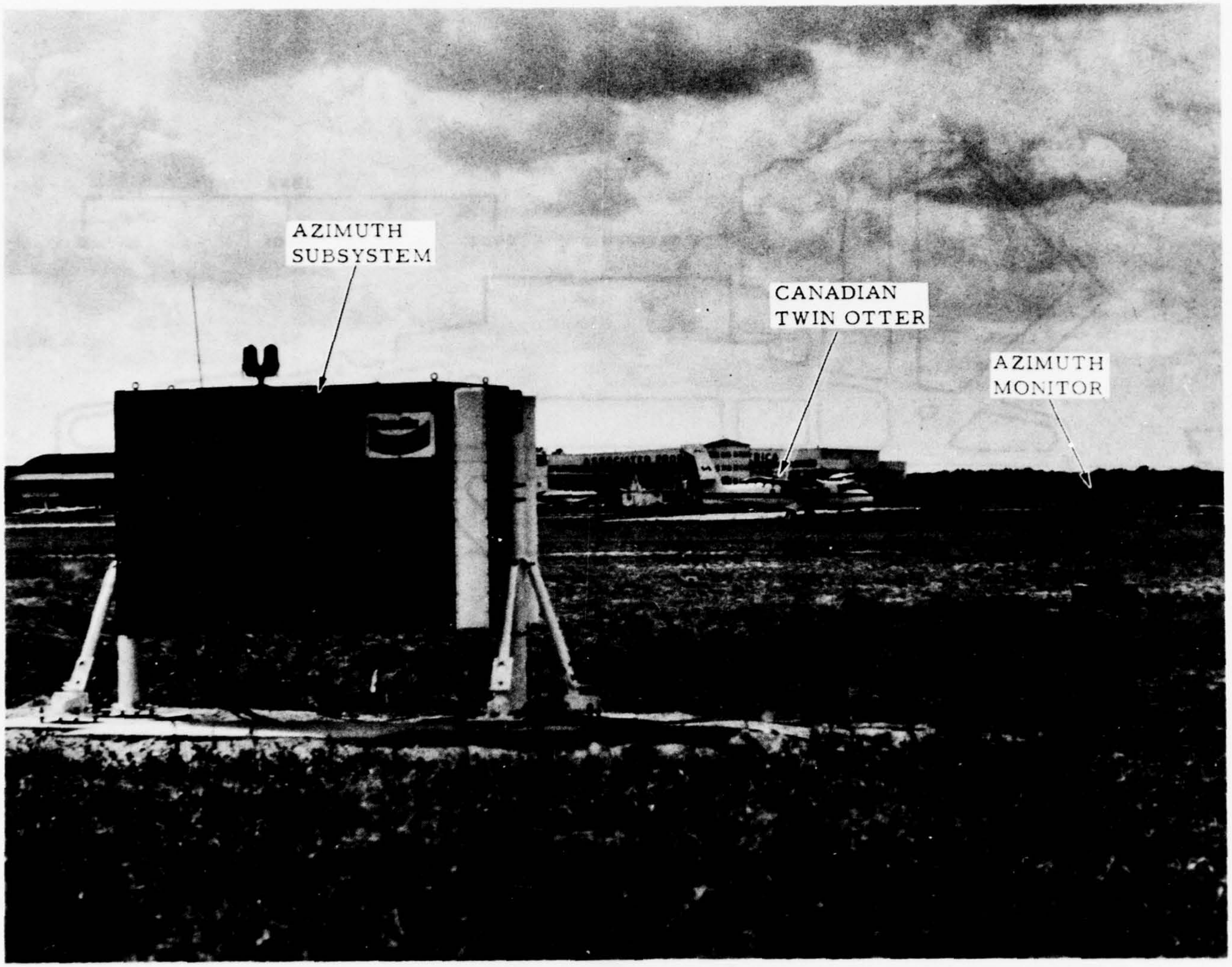


FIGURE 3. TRSB SMALL COMMUNITY SYSTEM AZIMUTH SUBSYSTEM

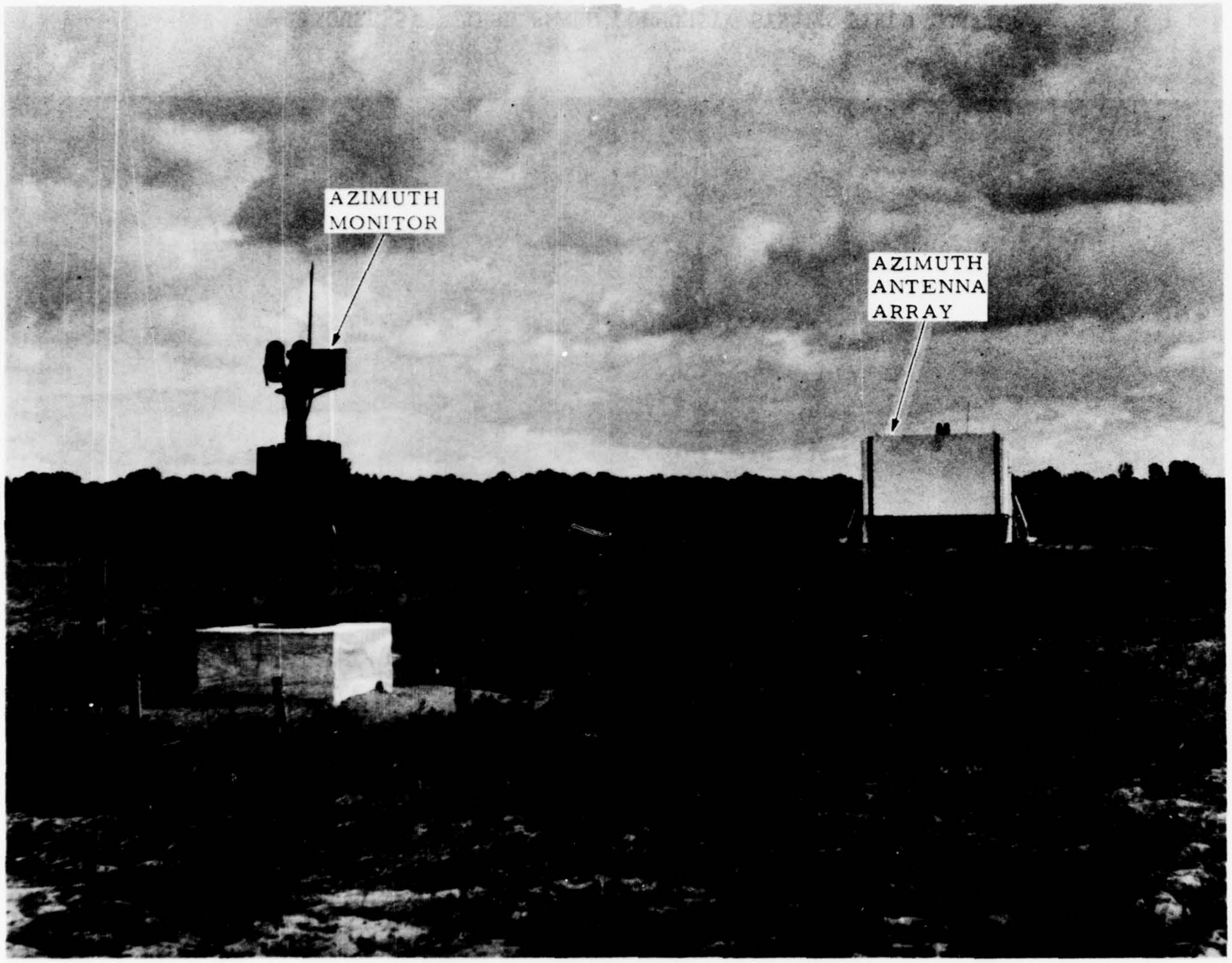


FIGURE 4. TRSB SMALL COMMUNITY SYSTEM AZIMUTH ARRAY AND MONITOR

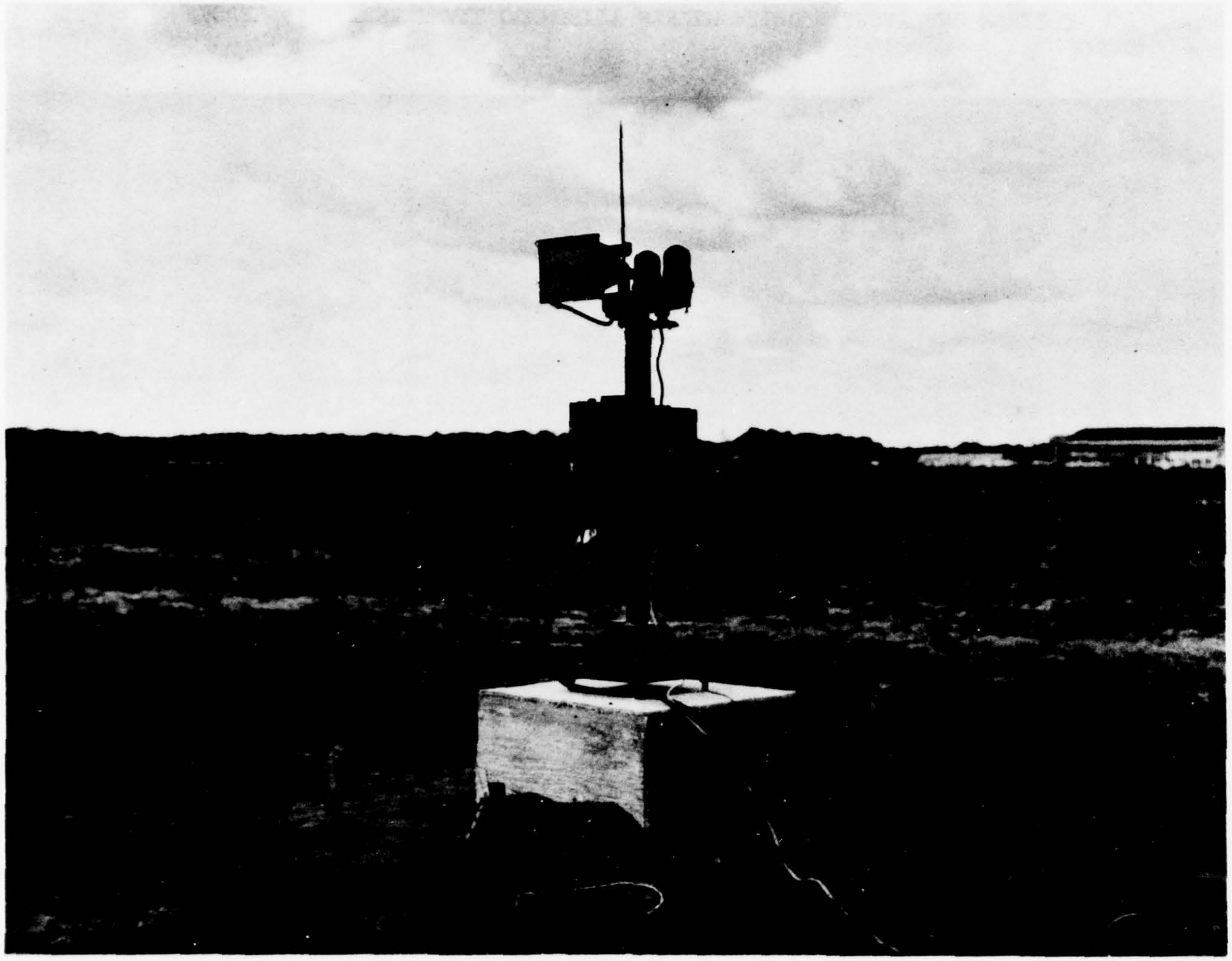


FIGURE 5. TRSB SMALL COMMUNITY SYSTEM FIELD MONITOR

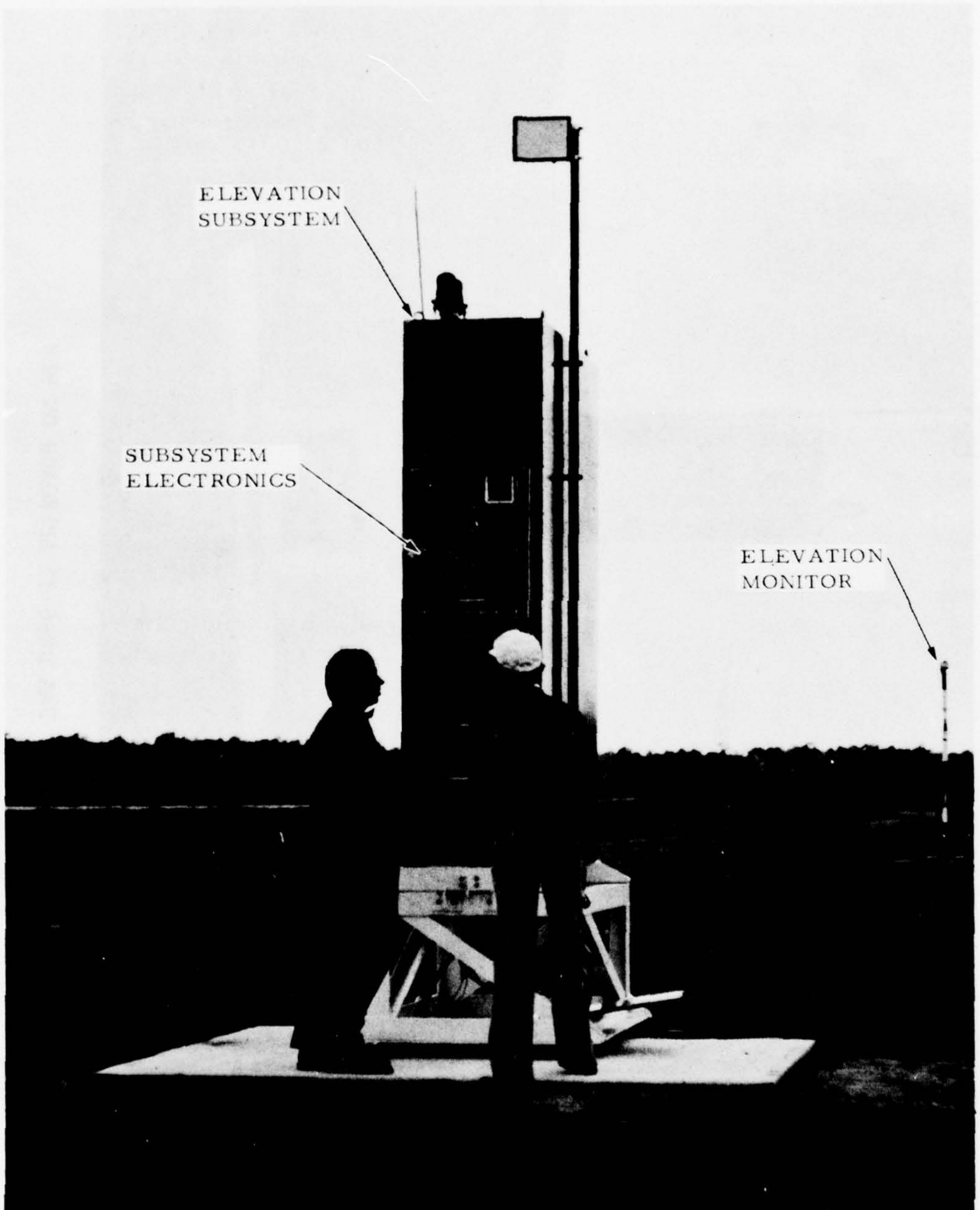


FIGURE 6. TRSB SMALL COMMUNITY SYSTEM ELEVATION SUBSYSTEM AND MONITOR

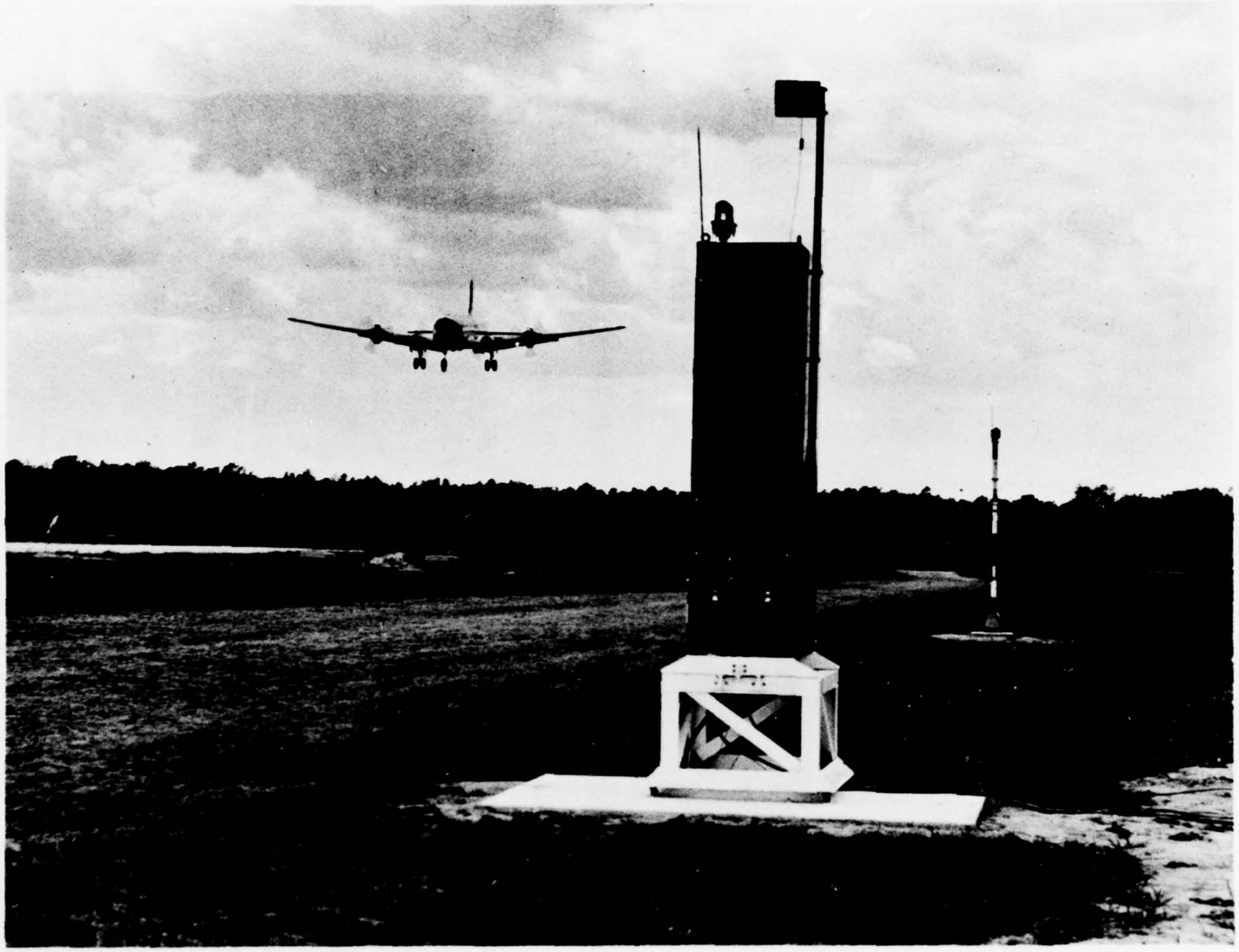


FIGURE 7. FAA DC-6 3° APPROACH ON MLS

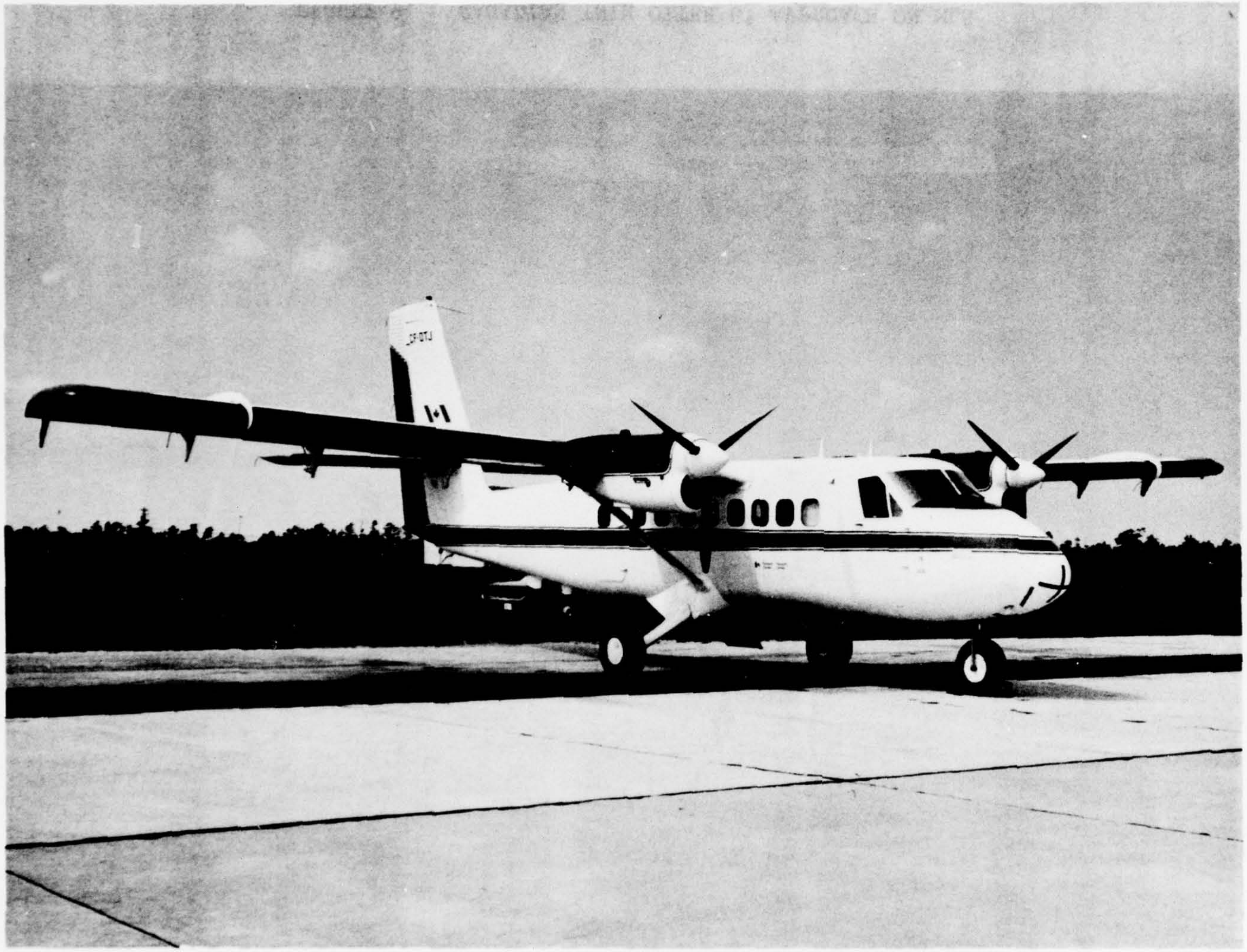


FIGURE 8. CANADIAN MOT TWIN OTTER

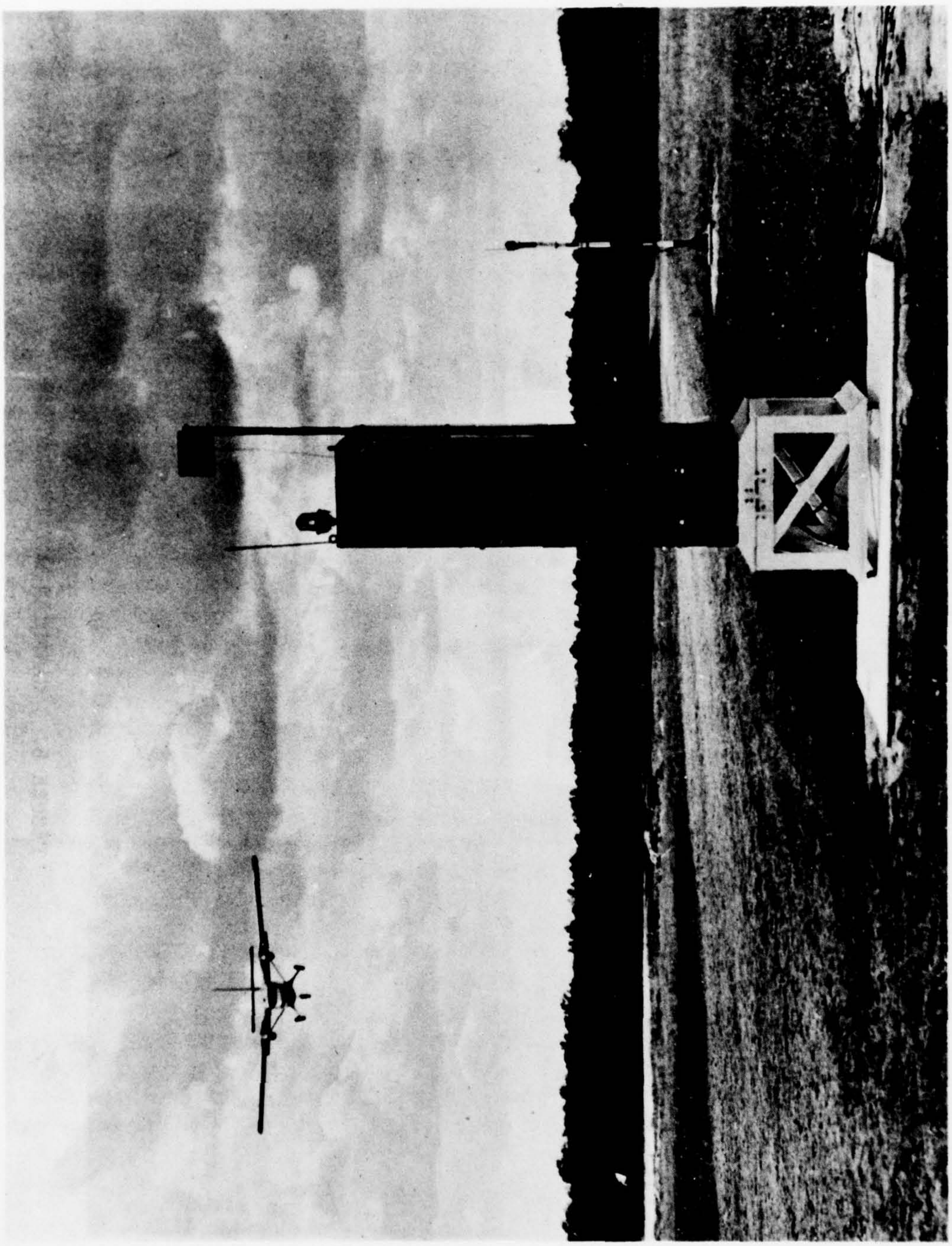


FIGURE 9. CANADIAN TWIN OTTER 6° APPROACH ON MLS

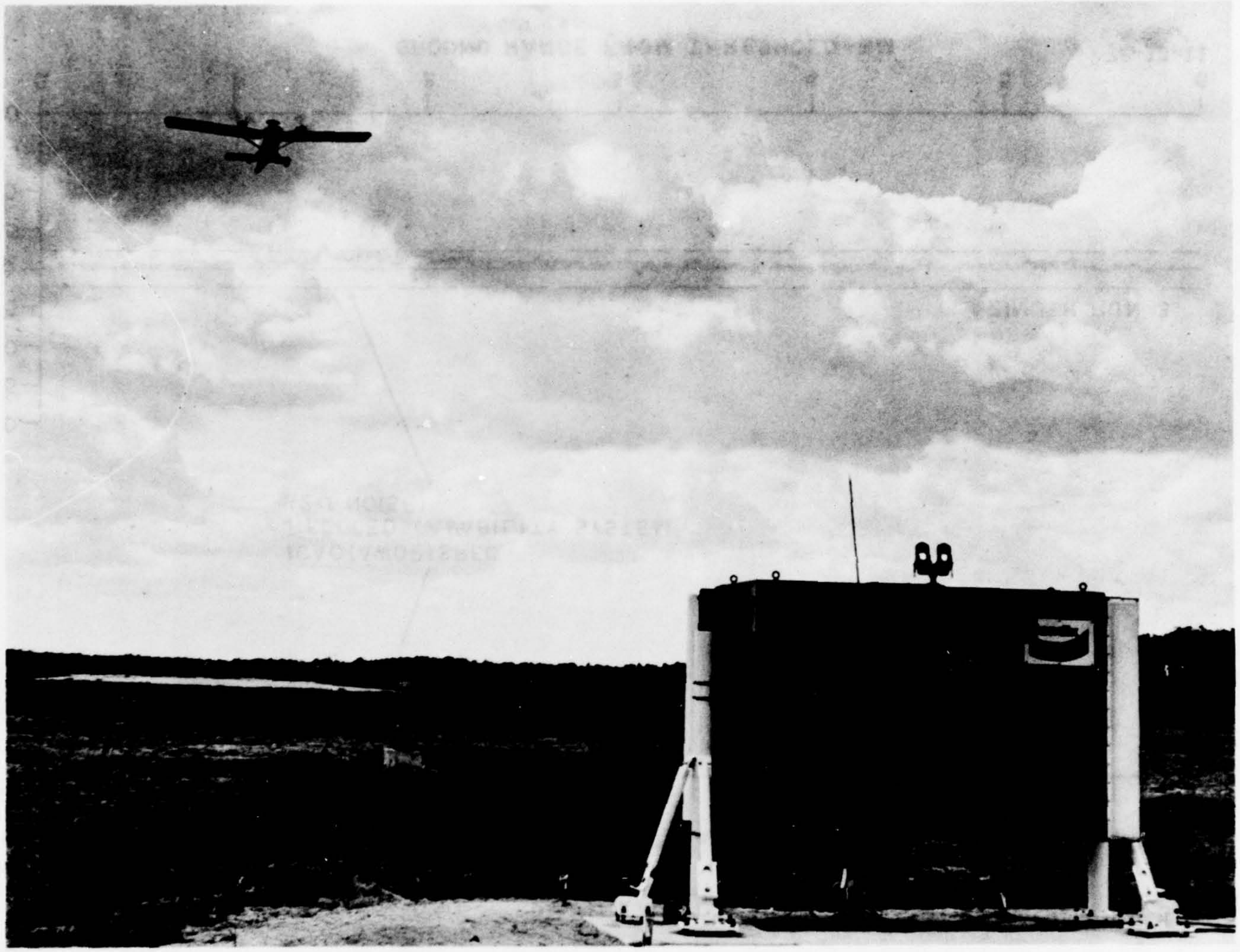


FIGURE 10. CANADIAN TWIN OTTER AFTER TAKE-OFF FROM RUNWAY 10-28

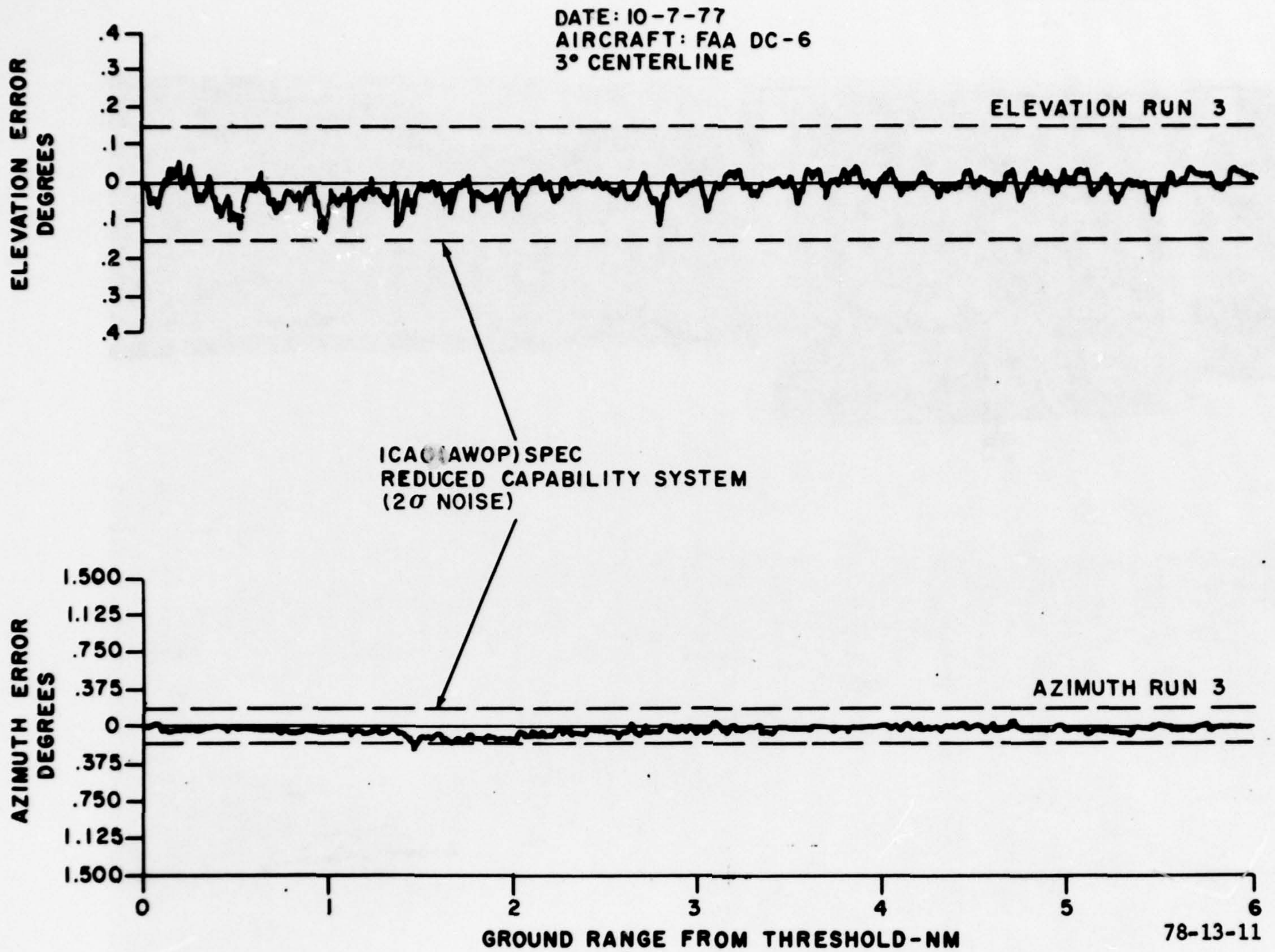


FIGURE 11. SMALL COMMUNITY SAMPLE DATA (RUN 3)

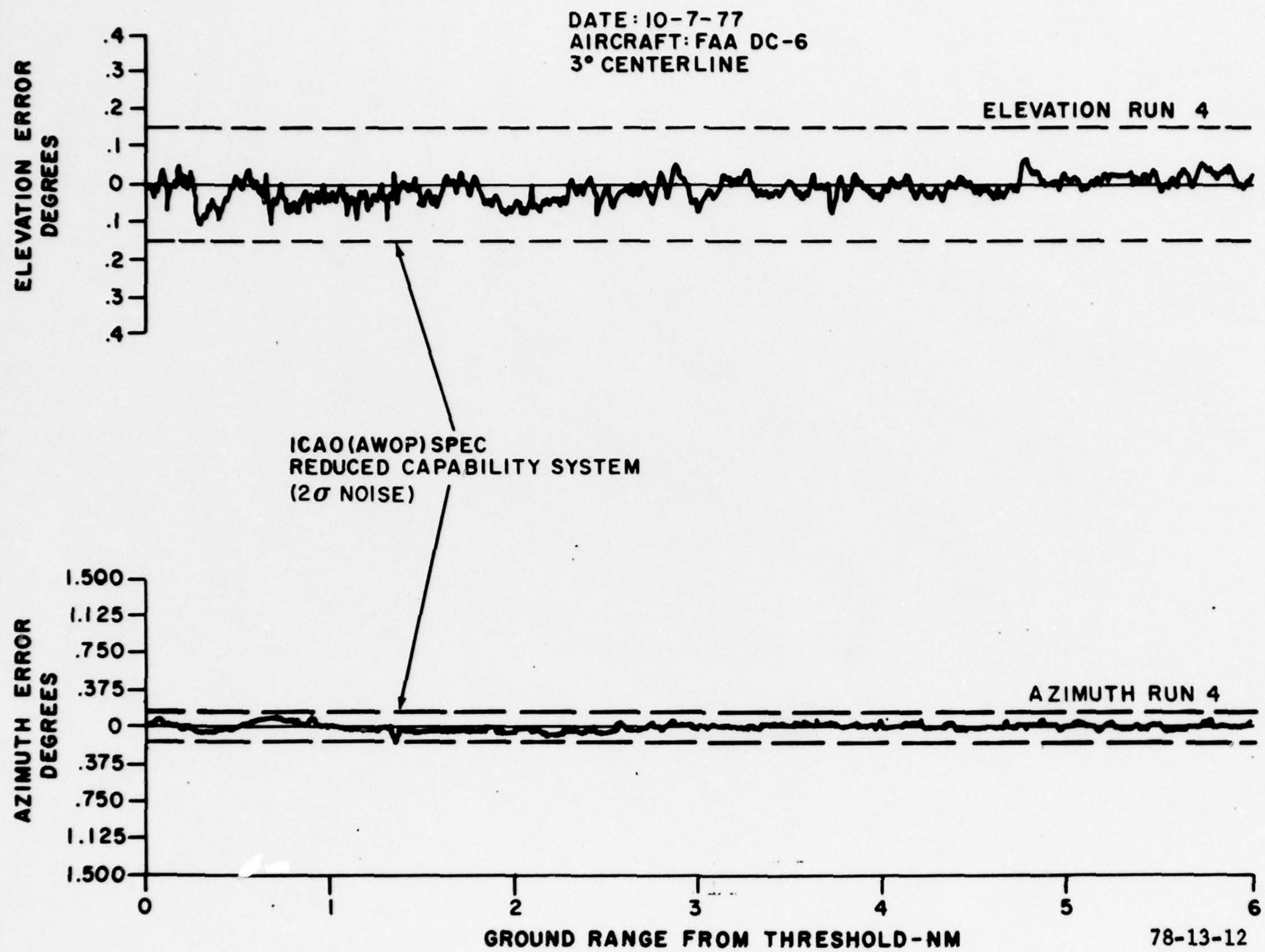
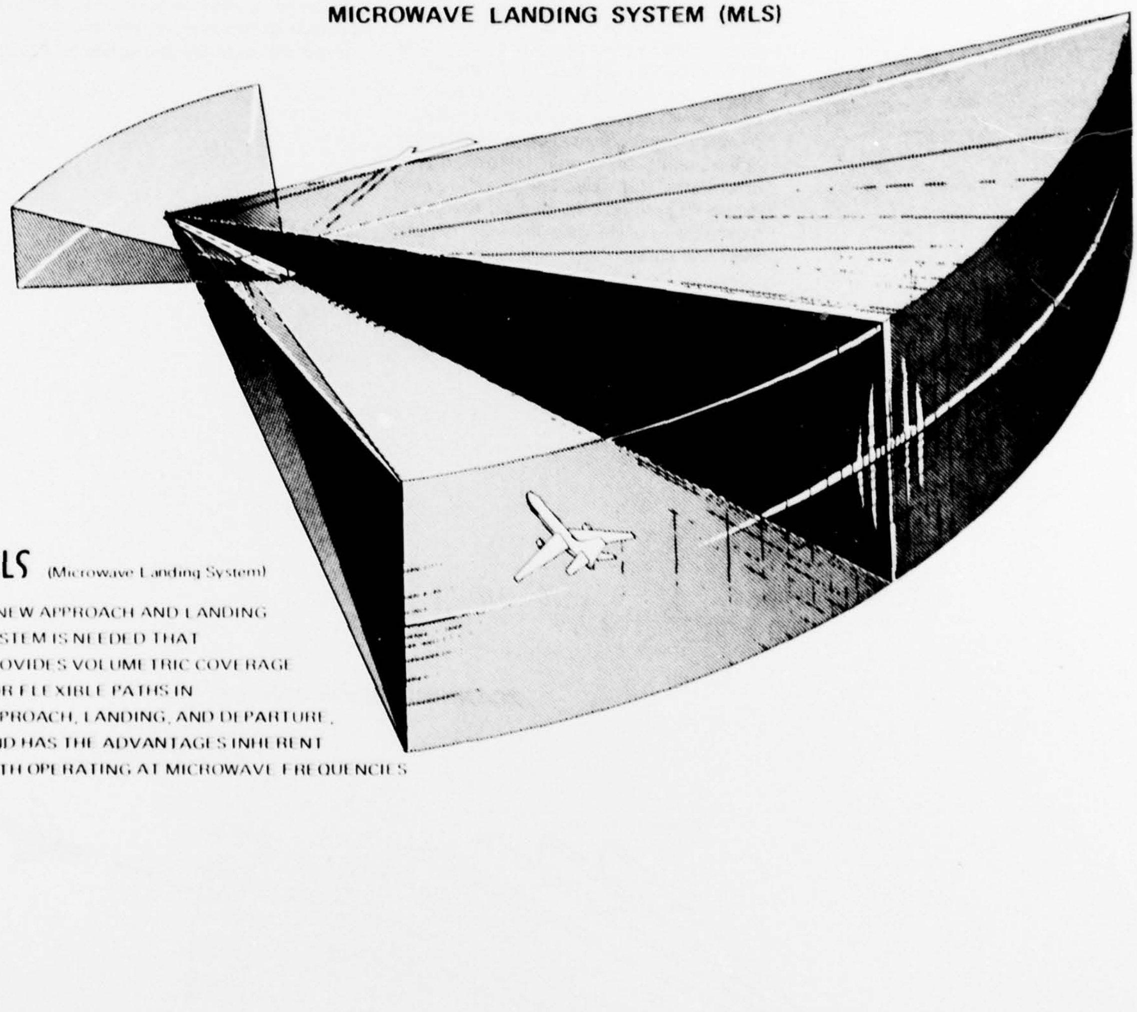


FIGURE 12. SMALL COMMUNITY SAMPLE DATA (RUN 4)

APPENDIX A

MICROWAVE LANDING SYSTEM (MLS)



MLS (Microwave Landing System)

A NEW APPROACH AND LANDING SYSTEM IS NEEDED THAT PROVIDES VOLUMETRIC COVERAGE FOR FLEXIBLE PATHS IN APPROACH, LANDING, AND DEPARTURE, AND HAS THE ADVANTAGES INHERENT WITH OPERATING AT MICROWAVE FREQUENCIES

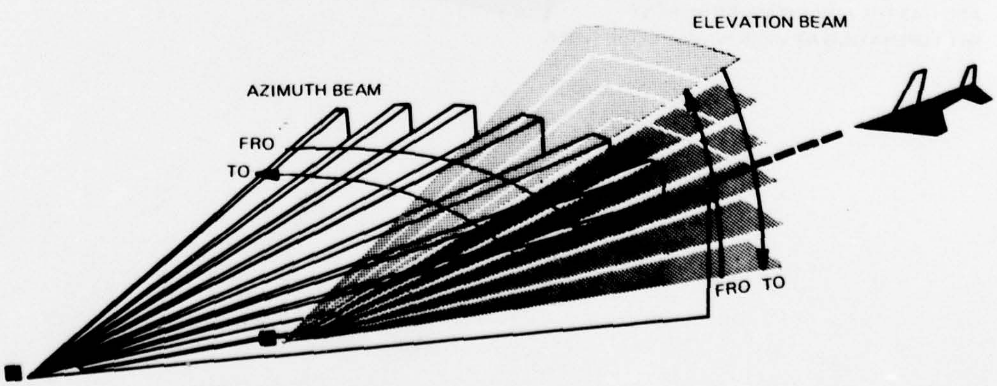
TIME REFERENCE SCANNING BEAM (TRSB) MLS IS AN AIR-DERIVED APPROACH AND LANDING SYSTEM. An aircraft can determine its position in space by making two angle measurements and a range measurement. A simple ground-to-air data capability provides airport and runway identification and other operational data (such as wind speed and direction, site data, and system status).

FAN BEAMS PROVIDE ALL ANGLE GUIDANCE (APPROACH AZIMUTH, ELEVATION, FLARE, AND MISSED APPROACH). The TRSB ground transmitter supplies angle information through precisely timed scanning of its beams and requires no form of modulation. Beams are scanned rapidly "to" and "fro" throughout the coverage volume as shown below. In each complete scan cycle, two pulses are received in the aircraft—one in the "to" scan, the other in the "fro" scan. The aircraft receiver derives its position angle directly from the measurement of the time difference between these two pulses.

RANGE IS COMPUTED IN THE CONVENTIONAL MANNER. TRSB proposes to use L-Band Distance Measuring Equipment (DME) that is compatible with existing navigation equipment. It provides improved accuracy and channelization capabilities. The required 200 channels can be made available by assignment or sharing of existing channels, using additional pulse multiplexing. The ground transponder is typically collocated with the approach azimuth subsystem.

NOTE: *The DME (ranging) function is not discussed in detail because it is independent of angle guidance subsystems and therefore* **is not critical to the description of TRSB.**

SCANNING BEAM CONCEPT



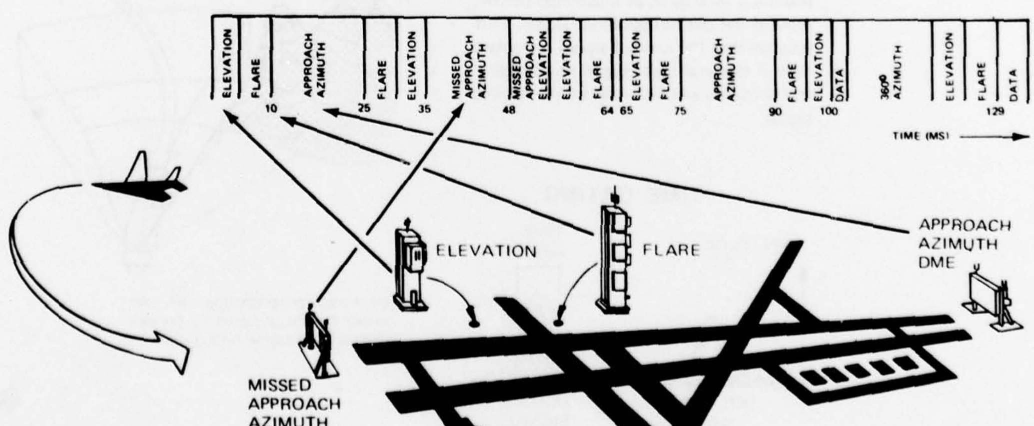
TRSB beams are scanned rapidly "to" and "fro" (back and forth for azimuth, down and up for elevation) at a precise rate

TRSB USES A TIME-SEQUENCED SIGNAL FORMAT FOR ANGLE AND DATA FUNCTIONS. Angle and data functions (that is, approach azimuth, elevation, flare, missed-approach guidance, and auxiliary data) are sequentially transmitted by the ground station on the same channel. Primary operation is C-band, with 300 KHz spacing between channels. However the format is compatible with Ku-Band requirements. (Note: DME is an independent function on a separate frequency and is not a part of this format.)

THE SIGNAL FORMAT IS DESIGNED TO ALLOW A MAXIMUM DEGREE OF FLEXIBILITY. Functions can be transmitted in any order or combination to meet the unique operational needs of each site. This flexibility is made possible by a function preamble identification message. This message sets the airborne receiver to measure the angle or decode the data function that will follow. The ordering or timing of transmissions, therefore, is not important. This flexibility permits individual functions to be added or deleted to meet specific airport requirements. It also permits any TRSB airborne receiver to operate with any ground system. The only requirements are that a minimum data rate (minimum number of to-fro time-difference measurements per second) be maintained for each angle function, and that these measurements be relatively evenly distributed in time. An example of two 64-millisecond sequences of a configuration that utilizes all available functions is illustrated below.

THE TRSB FORMAT PROVIDES FOR CURRENT AND ANTICIPATED FUTURE REQUIREMENTS. Included are

- Proportional azimuth angle guidance to ±60° relative to runway centerline at a 13.5-Hz update rate (that is, data are renewed 13.5 times each second.)
- Proportional missed-approach azimuth guidance to ±40° relative to runway centerline at a 6.75-Hz update rate
- Proportional elevation guidance up to 30° with a 40.5-Hz update rate
- Flare guidance up to 15° with a 40.5-Hz update rate
- 360° azimuth guidance with a 6.75-Hz update rate
- Missed-approach or departure elevation function with a 6.75-Hz update rate
- Basic data prior to each angle function (includes function identification, airport identification, azimuth scale factors, and nominal and/or minimum selectable glide slope)
- Auxiliary data (for example, environmental and airport conditions)
- Facility status data
- Ground test signals
- Available time for other data and/or additional future functions.

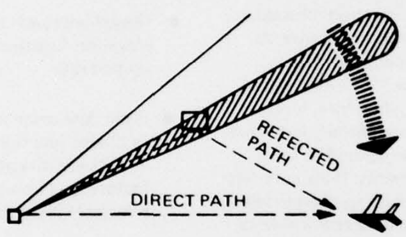


The TRSB signal offers maximum flexibility to meet unique user requirements

TRSB OPERATES EFFECTIVELY IN SEVERE MULTIPATH ENVIRONMENTS. TRSB offers several unique solutions to the multipath problem that has limited the implementation of other landing systems.

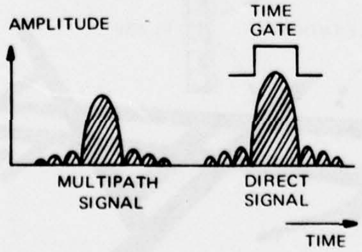
THERE ARE TWO TYPES OF MULTIPATH. Multipath occurs when a microwave signal is reflected from a surface, such as an airport structure, a vehicle, and certain types of terrain. The resulting reflected beam is classified as either out-of-beam multipath or in-beam multipath, depending on its time of arrival in the aircraft receiver relative to the direct signal.

REFLECTED SIGNALS



OUT-OF-BEAM MULTIPATH. If the angle and therefore the time between the reflected and direct beam are relatively large, the aircraft receiver is subjected to out-of-beam multipath. In this case, the TRSB processor automatically rejects the reflected signal by placing a time gate, as illustrated below, around the desired guidance signal. This ensures that the correct signal is tracked even if the multipath signal amplitude momentarily exceeds that of the desired signal.

TIME GATING



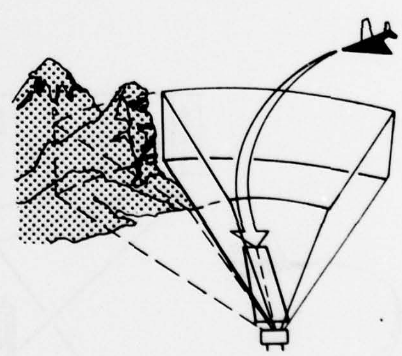
Time gating ensures that the correct signal is tracked, not the reflected one

IN-BEAM MULTIPATH. When the reflected and direct signals reach the aircraft almost simultaneously (the angle of arrival is very small), multipath is said to be in-beam. TRSB combats in-beam multipath by

- Shaping the horizontal pattern of the elevation antenna to reject lateral reflections
- Motion averaging, by utilizing the high data rates of TRSB
- Processing only the leading edge of the flare/elevation beam, which is not contaminated by the ground reflections.

COVERAGE CONTROL IS AVAILABLE TO ELIMINATE MULTIPATH AT EXTREMELY SEVERE PROBLEM SITES. Any MLS system will experience acquisition or tracking problems in those cases where the reflected signal is known to be persistent and greater in amplitude than the direct signal. A TRSB feature called coverage control can be implemented, at no cost, in such cases by simply programming the Beam Steering Unit (BSU). This feature permits a simple adjustment of the ground facility to limit the scan sector in the direction of the obstacle and thereby prevents acquisition of erroneous signals.

SELECTIVE COVERAGE CONTROL



By simple programming, the scan sector can be adjusted to prevent *undesired obstacle reflections*

TRSB IS A MODULAR SYSTEM WHICH CAN BE CONFIGURED TO MATCH THE NEEDS OF THE USER. A set of phased-array subsystems has been designed that may be installed in any combination to meet the broad range of user requirements.

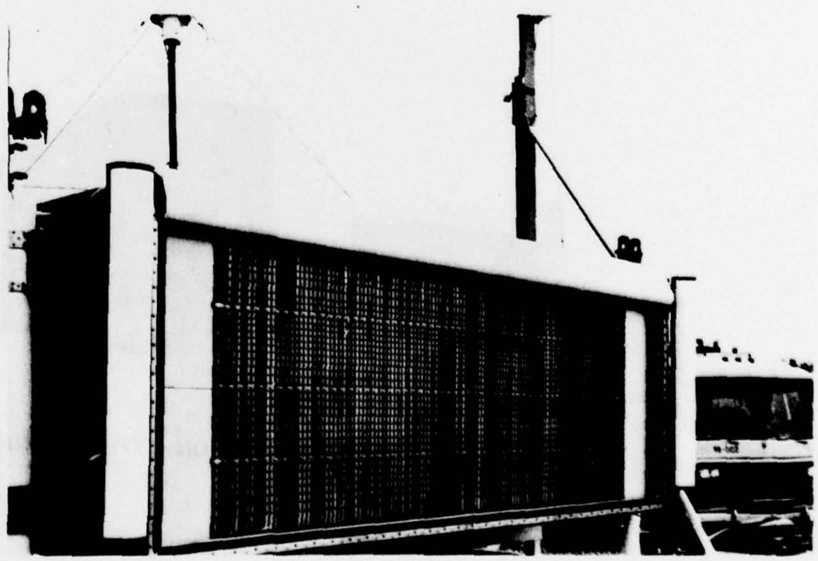
The minimum system configuration consists of approach azimuth and elevation subsystems. Flare, missed-approach, and range subsystems may be included or added later. Several antenna beamwidths are available, as indicated in the table below, from which a ground configuration can be designed to provide guidance signals-in-space of uniform quality in all airport environments.

NOTE: DME is an independent subsystem which is combined with appropriate azimuth and elevation subsystems to make up the total guidance system.

GROUND ANGLE SUBSYSTEMS

SUB-SYSTEM	NOMINAL BEAMWIDTH (DEGREES)	COVERAGE (DEGREES) *	PRINCIPAL APPLICATIONS
Azimuth	1	Up to ± 60	Approach Azimuth; Long Runways
Azimuth	2	Up to ± 60	Approach Azimuth; Intermediate Length Runways
Azimuth	3	Up to ± 60	Approach Azimuth; Short Runways Missed Approach Azimuth
Elevation	0.5	Up to 15	Flare
Elevation	1	Up to 30	Elevation (Severe multipath sites)**
Elevation	2	Up to 30	Elevation (Less severe multipath sites)**

* Coverage determined by Beam Steering Unit (BSU) for all arrays.
** **See multipath discussion.**



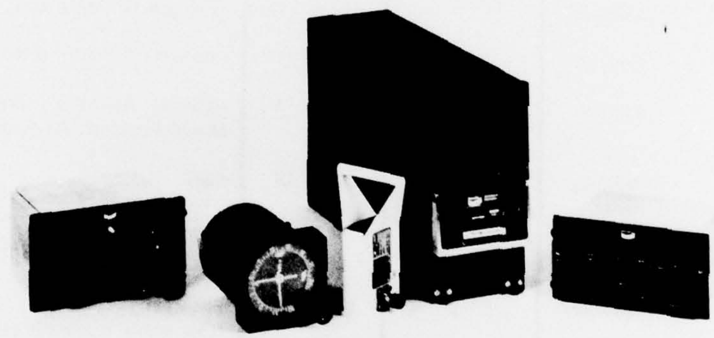
Phased Array Azimuth Antenna installed at the National Aviation Facilities Experimental Center. Radome is rolled back to expose radiating elements.

AIRBORNE RECEIVER DESIGNS ALSO *STRESS THE MODULARITY CONCEPT.* Users need only procure what is necessary for the services desired from any ground facility. To obtain approach and landing guidance at the lowest cost, an aircraft needs only an antenna and a basic receiver-processor unit operating with existing ILS displays. *An air-transport category aircraft* equipped for operation to low-weather minimums will carry redundant equipment and, in the future, advanced displays to fully utilize all of the inherent operational *capabilities provided by* TRSB.

The 200-channel TRSB angle receiver-processor provides angle information from the scanning beam azimuth and elevation *subsystems and decodes the auxiliary data* for display. Special monitoring ensures the integrity of the receiver output.

A second airborne unit is the DME. It is channeled to operate with the angle receiver-processor and provides a continual *readout* of distance.

Both the angle receiver-processor and the DME provide standard outputs to existing flight instruments and autopilot systems. An *optional airborne computer would be used* to generate curved or segmented approaches based on TRSB position information.



AIRLINE TYPE AVIONICS

GENERAL AVIATION TYPE AVIONICS

TRSB CAN PROVIDE ALL-WEATHER LANDING CAPABILITY AT MANY RUNWAYS THAT PRESENTLY DO NOT OFFER THIS SERVICE. This is made possible by

- The proposed channel plan, which contains enough channels for any foreseeable implementation
- High system integrity and precision
- Minimum siting requirements.

THE LARGE COVERAGE VOLUME PROVIDES FLIGHT PATH FLEXIBILITY. Transition from en route navigation is enhanced through the wide proportional coverage of MLS. Such flexibility in approach paths, coupled with high-quality guidance, can be used to achieve

- Improvements in runway and airport arrival capacity
- Better control of noise exposure near airports
- Optimized approach paths for future V/STOL aircraft
- Intercept of glide path and of runway centerline extended without overshoot
- Lower minimums at certain existing airports by providing precise missed-approach guidance
- Wake vortex avoidance flight paths.

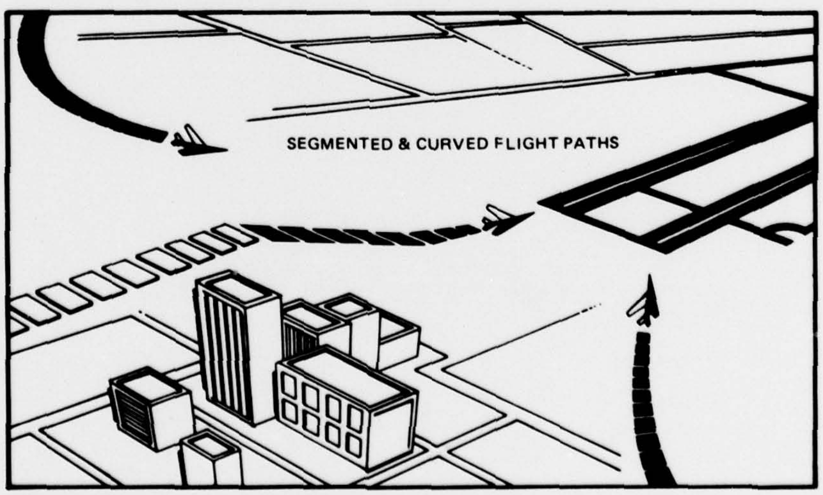
THE TRSB SIGNAL FORMAT ENSURES THAT EVERY AIRBORNE USER MAY RECEIVE LANDING GUIDANCE FROM EVERY GROUND INSTALLATION. Compatibility is ensured between facilities serving international civil aviation and those serving unique national requirements.

TRSB SPANS THE ENTIRE RANGE OF APPROACH AND LANDING OPERATIONS FOR ALL AIRCRAFT TYPES. This includes CTOL, STOL, and VTOL aircraft operating over a wide range of flight profiles. The particular needs of users, ranging from general aviation to major air carriers, are accommodated. TRSB is adaptable to special military applications, such as transportable or shipboard configurations on a compatible basis with civil systems.

HIGH RELIABILITY, INTEGRITY, AND SAFETY OF TRSB ARE ENHANCED BY SEVERAL IMPORTANT FEATURES. These include

- Simple TRSB receiver processing
- Multipath immunity features on the ground and in the airborne receiver-processor
- A comprehensive monitoring system that verifies the status of all subsystems and the radiated signal. Status data are transmitted to all aircraft six times each second.
- Coding features, such as parity and symmetry checks, that prevent the mixing of functions.

TRSB PROVIDES CATEGORY-III QUALITY GUIDANCE. TRSB signal guidance quality has already been proved via demonstration of fully automatic landings, including rollout, in a current commercial transport aircraft (Boeing 737) and an executive jet (North American Sabreliner).



TRSB provides precision guidance for curved and segmented approaches for noise abatement and traffic separation, as well as for autoland and rollout